

Findings

Digital Images: Clinical Applications

The panel notes that electronic imaging is having a major impact on the conduct of clinical medicine. Particularly affected are the disciplines of neurology, reconstructive surgery (especially facial and oral surgery), neurosurgery, orthopedics, radiology, and radiation therapy. A growing emphasis on 3-D spatial information for treatment planning now supplements the traditional role of radiologic studies in diagnosis.

In some specialties such as neurology, imaging studies serve as a screening procedure prior to requesting clinical consultation; clinical signs and symptoms are sometimes subordinated to imaging results in the management of patients, and referrals for asymptomatic abnormal imaging results are increasingly common. Stereotactic guidance for neurosurgical procedures using 3-D imaging data is under development.

Management of traumatic, degenerative and congenital bony abnormalities, be they located in the head, thorax, or major joints, now often includes pre-operative 3-D imaging as an adjunct to therapy planning. The uses of imaging in this area include visual displays intended to convey a clear anatomic model to the physician. In addition, computer imaging data can be linked to robotically controlled milling machines to produce models of pathologic tissue for practice operations, to build prosthetic devices to guide implantation and reconstruction, and to guide the selection and/or remodelling of artificial joint hardware to fit a particular patient. Industrial research is currently in progress to use such data to guide the actual robotic milling of bone and joint surfaces *in vivo*.

Additional therapy-planning uses of volumetric digital imaging include the matching of donor organ and recipient cavity sizes in cases of heart and liver transplant, the preoperative sizing of malignant tumors such as musculoskeletal sarcomas, and radiation therapy planning from 3-D volumetric tumor models.

Digital Images: Educational Applications

The panel recognizes that 3-D image reconstruction by computer provides a new and promising method for the education of health professionals. The understanding of complex structure-function relationships such as those in the central nervous system is a challenging educational problem which is

only poorly solved by two dimensional images, physical models, and cadaver dissections. The educational goal is the development of a clear three dimensional model in the mind of the student, and the integration of structural knowledge with physiological and biochemical function.

Just as the practicing surgeon might view abnormal, patient specific anatomy at a radiological workstation, the panel noted that a student's workstation would allow the display, rotation, selective "dissection" and reassembly of normal human anatomy by the student, controlled by graphical pointing devices and easy-to-use interface methods. Such methods would also greatly facilitate the understanding of congenital abnormalities and aid the planning of their corrections by rendering the existing collections of human embryos (e.g., Carnegie Collections, Blechschmidt Collection) in computer readable form. Initial work to develop both geometrical and image-based teaching files and control software is under way at several university centers.

*Digital Images:
Research Applications*

Biomedical research presents special requirements for digital imaging. The need to correlate biochemical and physiologic data with anatomic location is especially acute in the neurosciences, where the recent discovery of large numbers of neurotransmitters and investigational techniques such as monoclonal antibody staining are generating a flood of new information which requires spatial mapping and correlation within the nervous systems of man and model systems such as rat brain. The tools for manipulating and sharing laboratory data add special requirements: the need to develop standardized formats for exchange of text, numeric, and graphical data among investigators; the need for user interface software which allows an investigator to easily view, edit, and compare the data from biochemical and neurocircuitry mapping experiments. Unlike the educational requirements for consensus standard image sets, research requirements emphasize the variability and one-of-a-kind nature of particular experiments.

Research imaging requirements for a National Neural Circuitry Database are the object of a study currently being funded by the Alcohol, Drug Abuse and Mental Health Administration (ADAMHA) and conducted by the Institute of Medicine. The panel recognizes the importance of coordinating digital imaging projects among the federal agencies which sponsor biomedical

research, and making available the knowledge resulting from that research.

*Digital Images and
Computer Networks*

The complex images of biology and medicine, as represented by digital volumetric data sets, constitute a challenge to currently available computer networks. Image files may range from hundreds of thousands to many millions of bits representing measures of volume (voxels) or points on a display screen (pixels). This contrasts with NLM's current bibliographic services where a database query may yield tens to a few thousands of alphanumeric characters, and wide area commercial networks providing 120 to 240 characters per second over voice-grade phone lines give acceptable response times. The transmission speed (bandwidth) necessary to accommodate image data will require that wide area networks be available with a capacity which equals or exceeds that currently found in local area networks (10-100 megabits/second).

*Digital Imaging and
the NLM*

The panel identifies a number of salient issues which bear upon National Library of Medicine involvement in digital image technologies and libraries. The most important of these are listed here.

Acquiring and providing access to digital image libraries is entirely consistent with the NLM's institutional mandate to acquire, organize, and make available the knowledge of medicine and biology. No such publicly available digital libraries currently exist. Clearly, the questions about this technology revolve around "when" and "how" the Library should proceed, not "if" the Library should proceed.

As noted by NLM's previous advisors, the greatest potential impact of NLM projects appears to be in the area of health professions education, where the establishment of image libraries representing normals and archetypal abnormals is an activity which cannot reasonably be undertaken by single academic institutions, and where there are few economic drivers in place to promote commercial development. However, educational institutions at the present time generally lack both the computer hardware of sufficient capacity, and the professional expertise among faculty to use 3-D computer images as a component of the curriculum. Indeed, the current emphasis upon molecular biological mechanisms of health and disease has led to a de-

emphasis of gross anatomy in the curriculum, and fewer hours dedicated to "structural biology." Faculty training and acceptance of new modalities such as computer-generated images is critical to the success of this technology in the educational process.

From a knowledge representation viewpoint, key issues remain in the development of methods to link spatial data--images and objects within images--to the symbolic data comprising the names, hierarchies, principles and theory which are the text-based understanding of visual things. The research group at the University of Washington has coined the term "Structural Informatics" to describe this field. Standards do not currently exist for such linkages among different data types, but this area of endeavor is new, rapidly changing, and the panel believes it is premature to insist upon such standards. In addition, much basic research is needed in the description and representation of morphological structures, and the connection of structural-anatomical to functional-physiological knowledge through the use of alternative modeling methods. Generalizable methods which support a hypertext-like model, where words can be used to find pictures, and pictures can be used as an index into relevant text, are needed.

Libraries of normal structures should be created so that they can be easily linked to related collections of diseased and abnormal structure, as well as those representing temporal variation (e.g., embryology). Research support by the NLM at key academic centers would assist in advancing the field, as would the convening of meetings to develop standards for data exchange and knowledge base sharing.

It is clear that the current environment is one of rapid change and new development in computers and algorithms designed for graphics manipulation and rendering. For this reason, the panel believes that NLM emphasize the creation, standardization, exchange and distribution of volumetric image databases, rather than the development of applications software which uses those databases.